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Davis et al.

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(54) **SEMICONDUCTOR DEVICES HAVING 3-DIMENSIONAL INDUCTIVE STRUCTURES**

H01L 23/62; H01L 23/5283; H01L 23/53257; H01L 27/11551; H01L 27/11578; H01L 28/10

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See application file for complete search history.

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Related U.S. Application Data

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H01L 23/532 (2006.01)
H01L 23/66 (2006.01)
H01L 23/62 (2006.01)
H01L 49/02 (2006.01)

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(57) **ABSTRACT**

Semiconductor devices having inductive structures, and associated systems and methods, are disclosed herein. In one embodiment, a semiconductor device includes a substrate and at least one circuit component coupled to the substrate. The semiconductor device can further include an inductive structure carried by the substrate and having a stack of alternating first and second layers. In some embodiments, the first layers comprise an oxide material and the second layers each include a coil of conductive material. The coils of conductive material can be electrically coupled (a) together to form an inductor and (b) to the at least one circuit component.

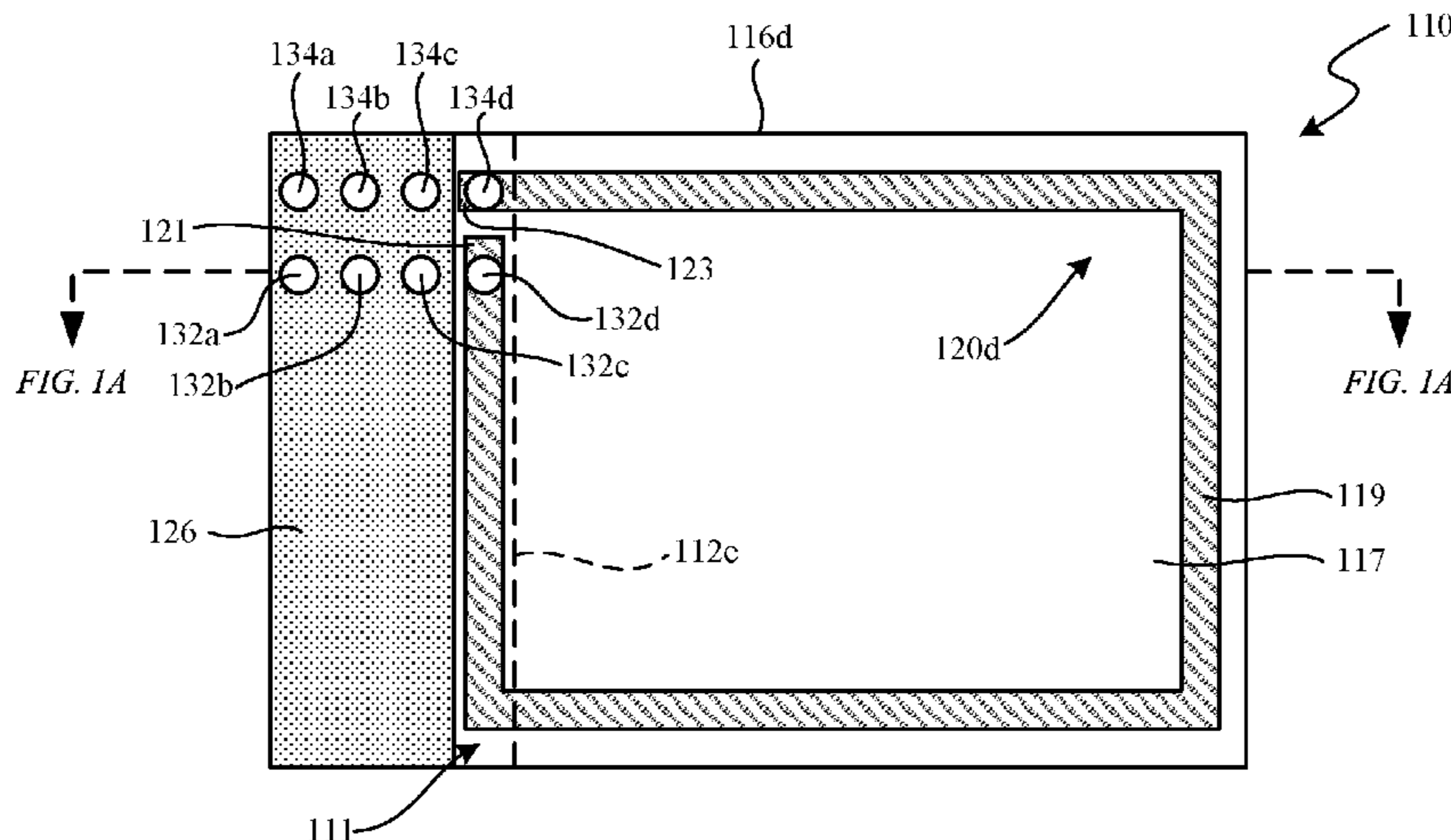
(52) **U.S. Cl.**

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20 Claims, 9 Drawing Sheets



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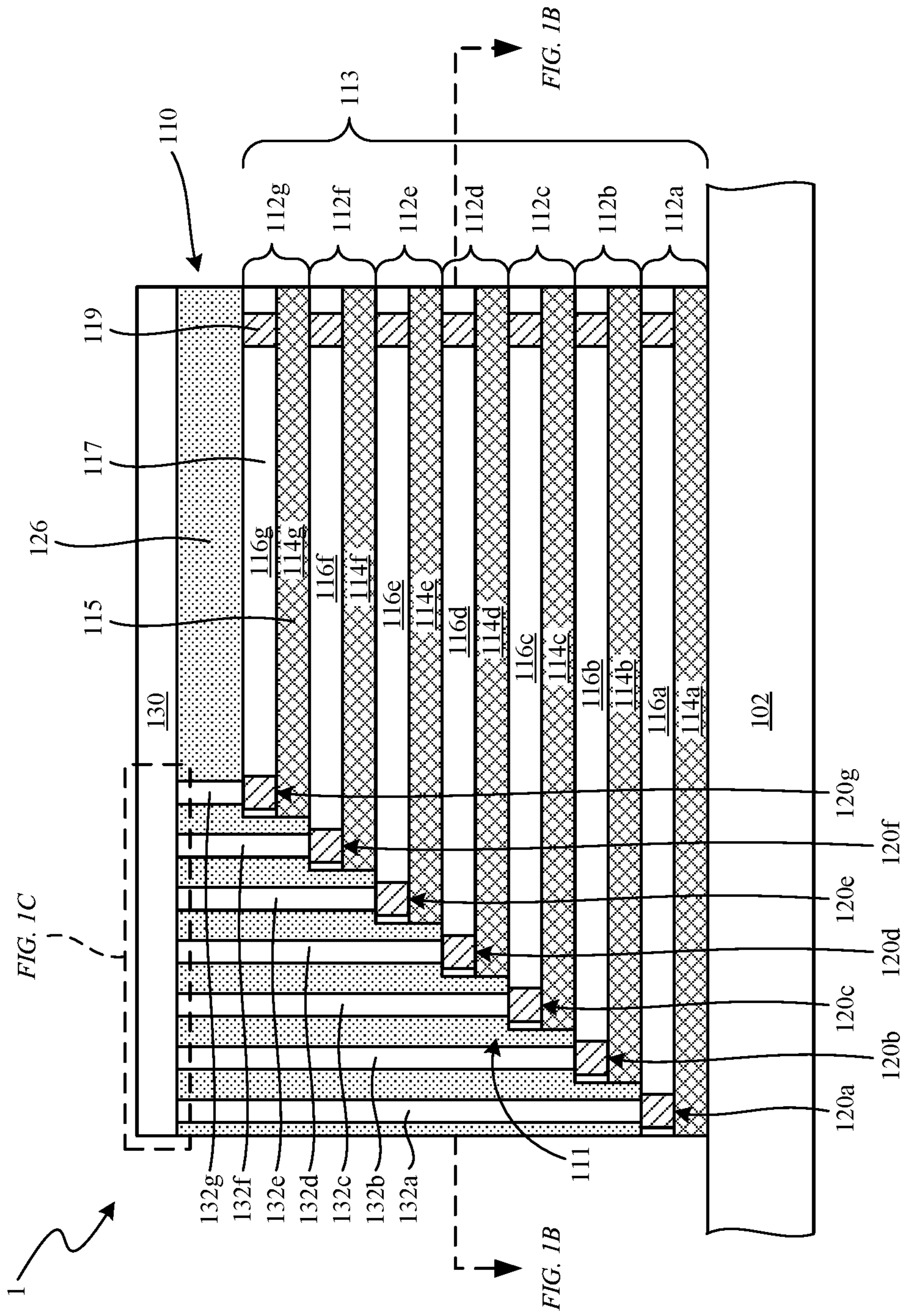


FIG. 1A

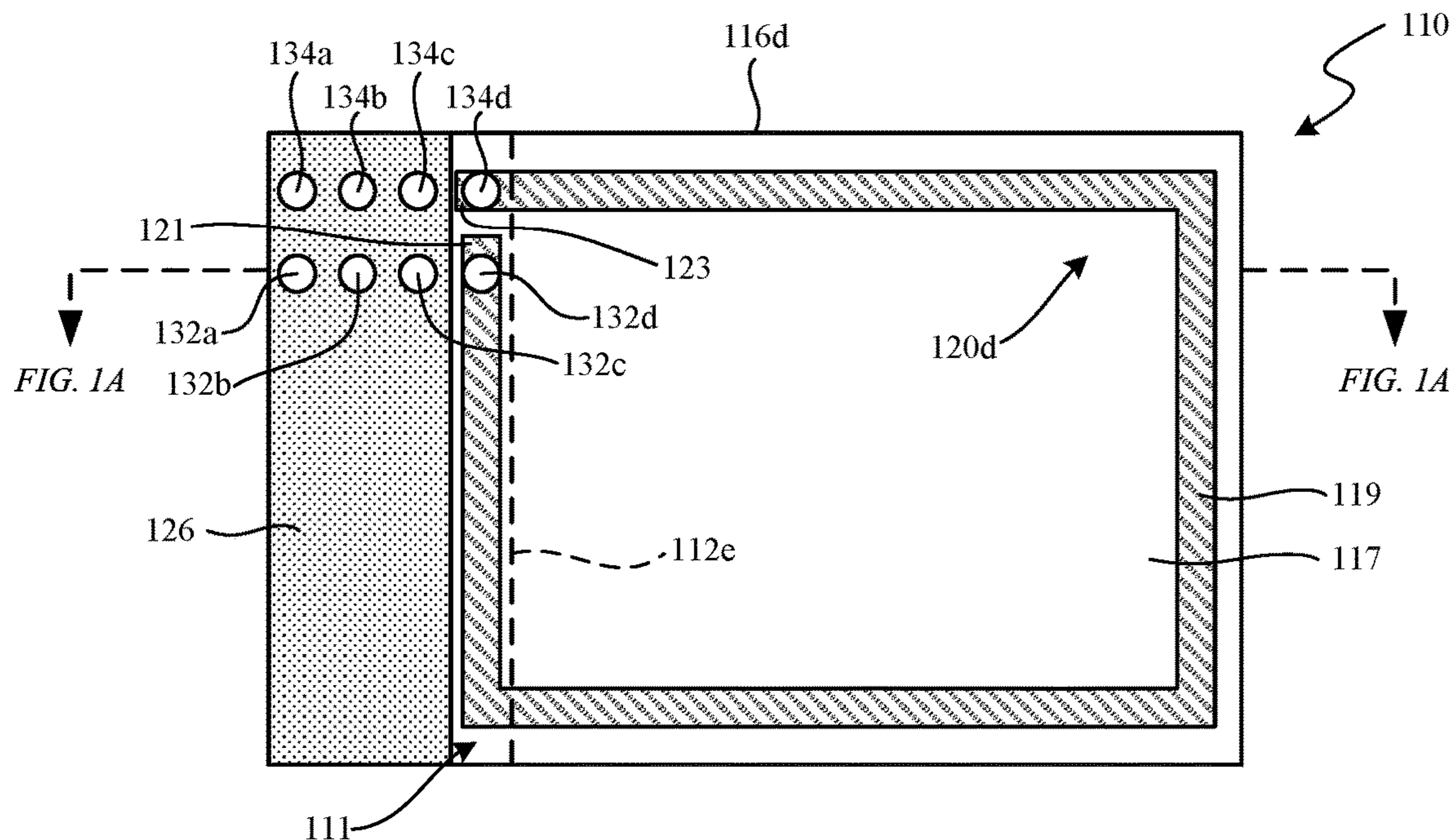


FIG. 1B

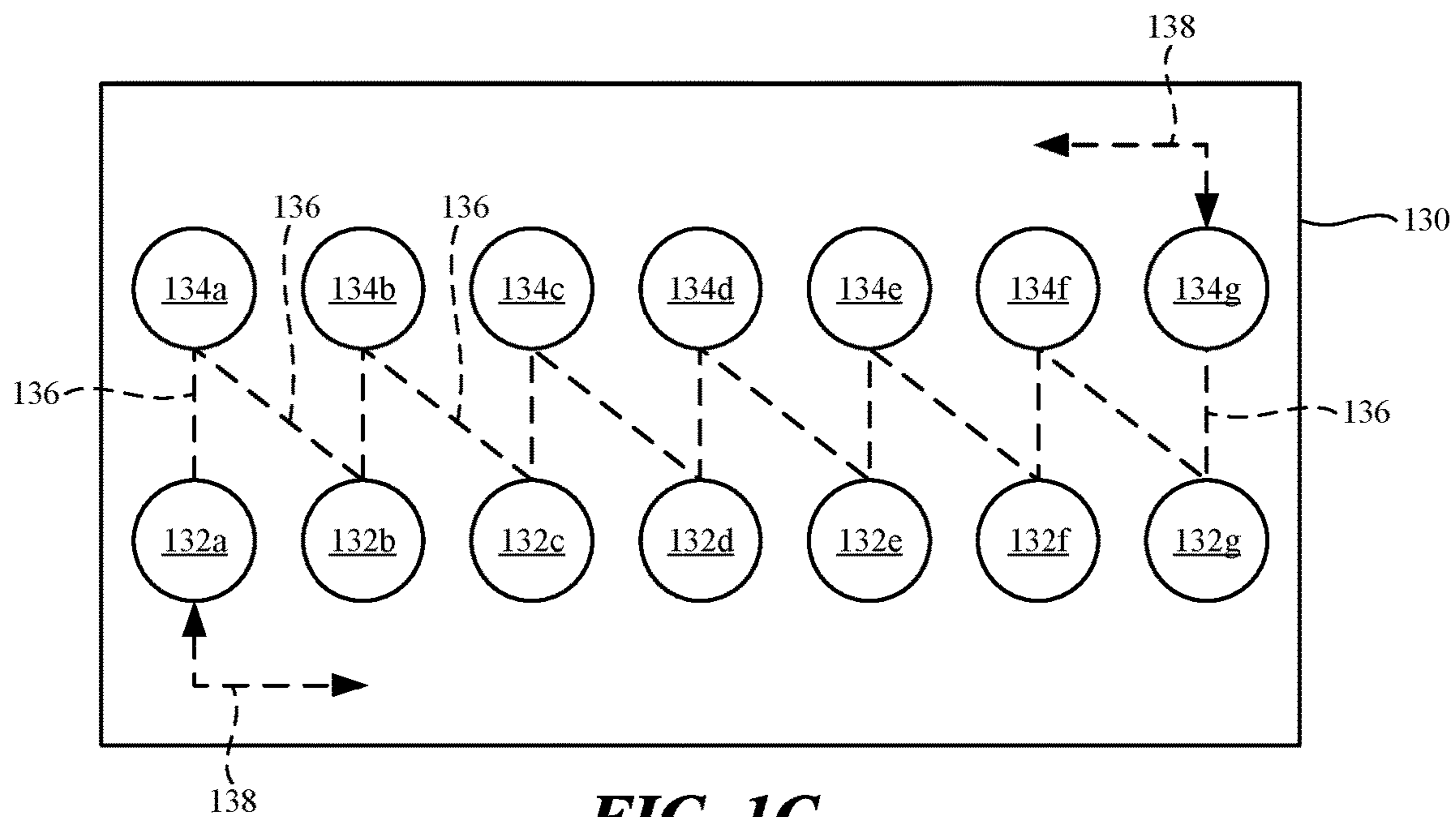


FIG. 1C

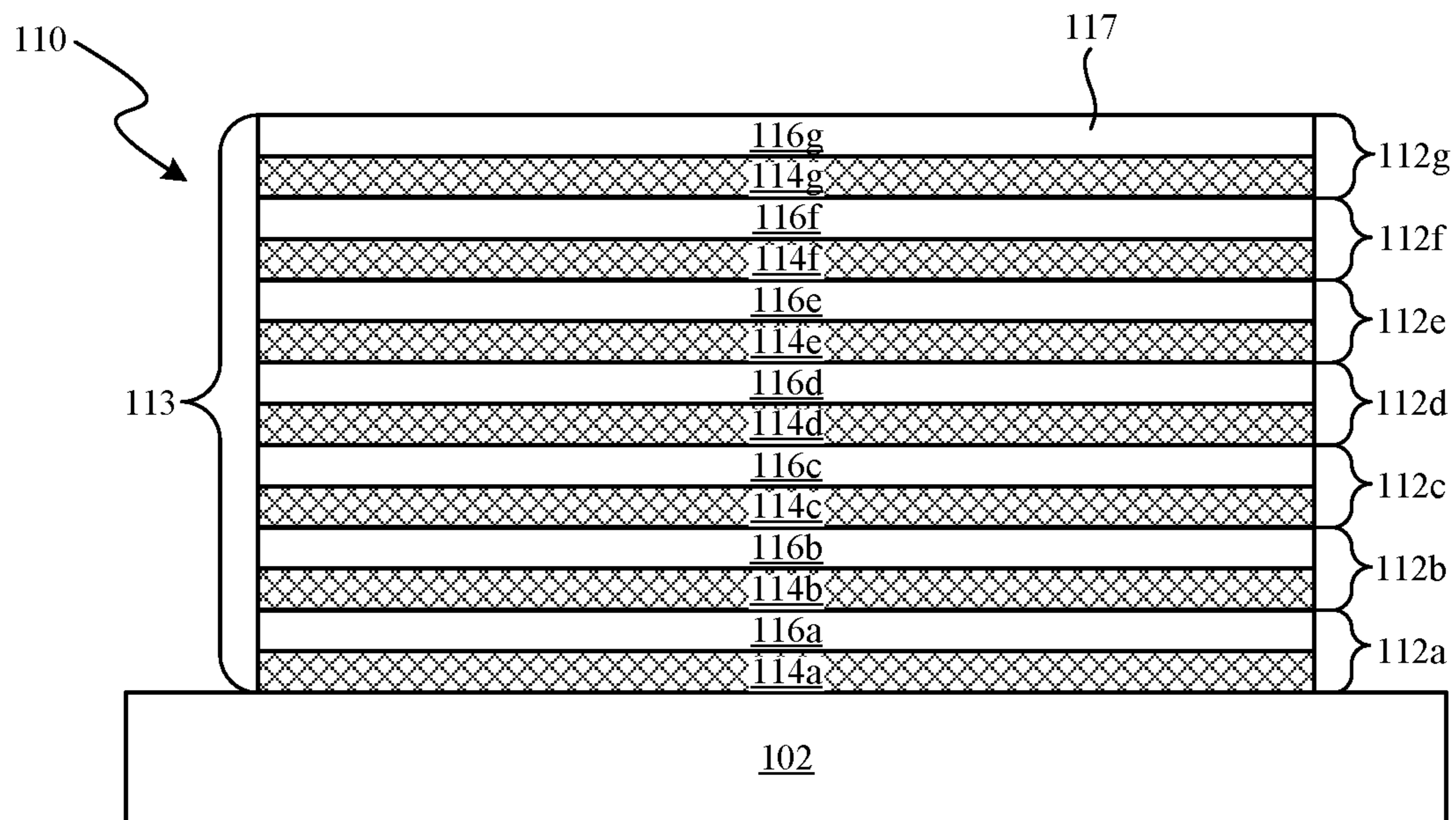


FIG. 2A

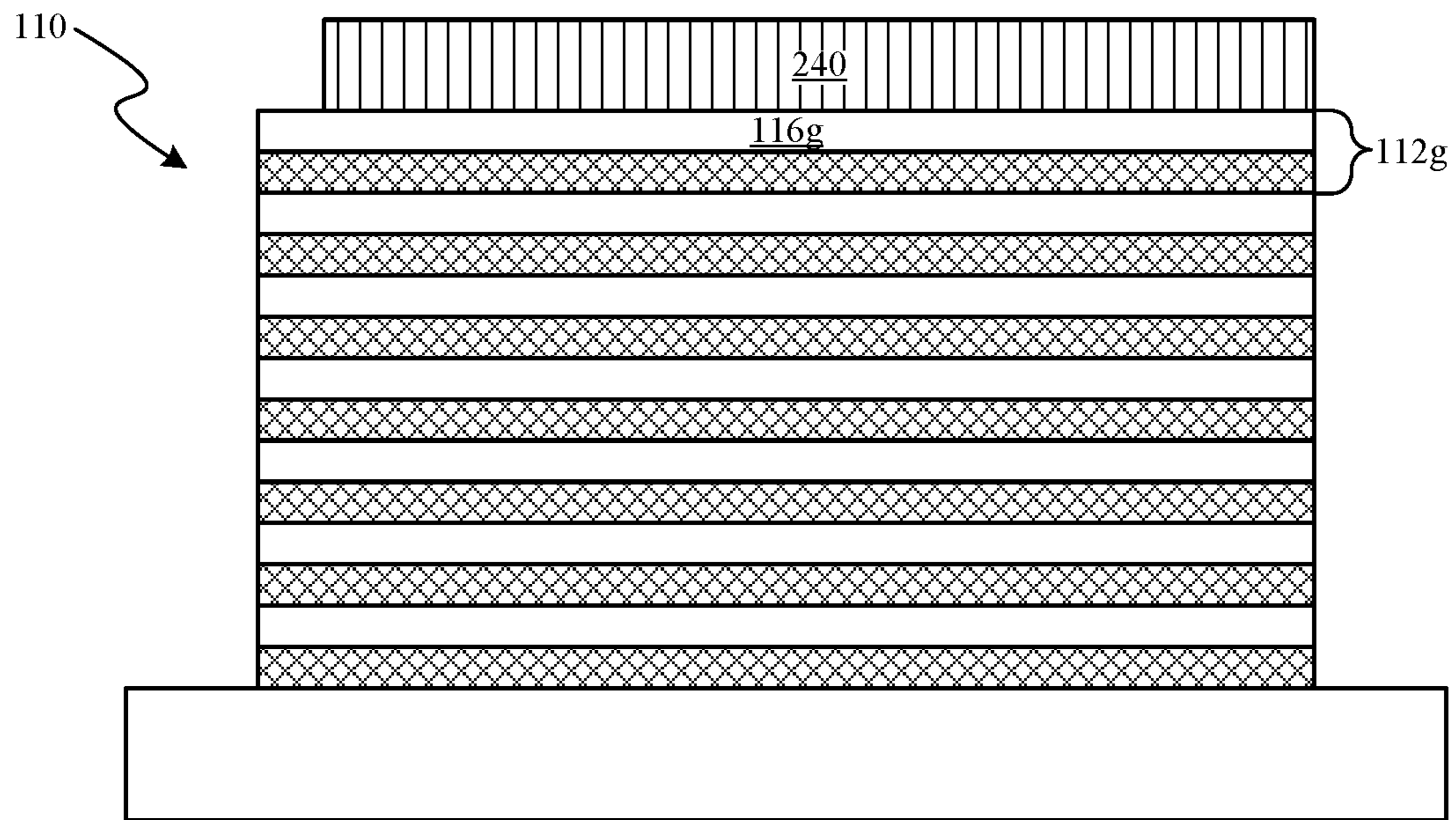


FIG. 2B

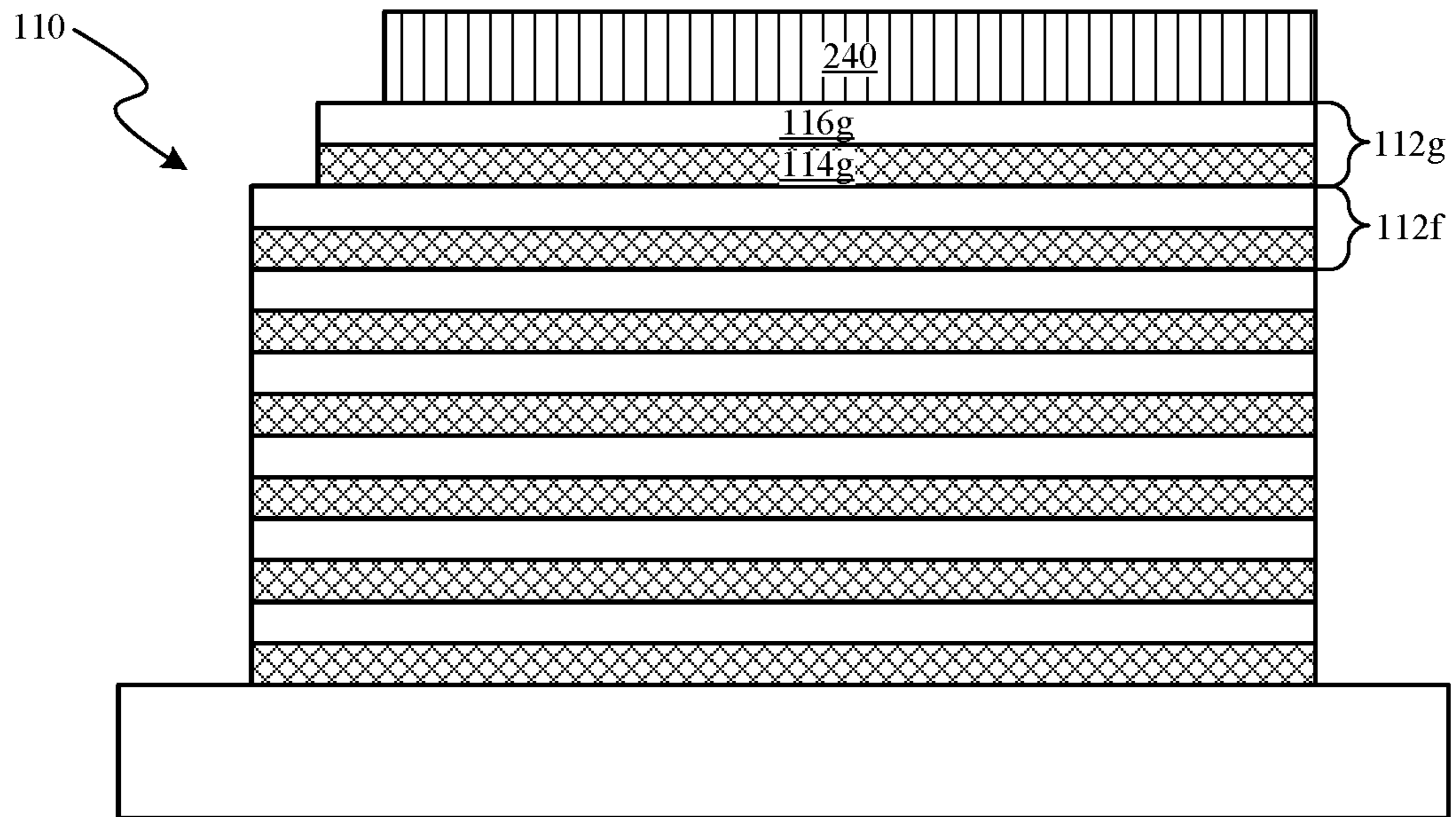


FIG. 2C

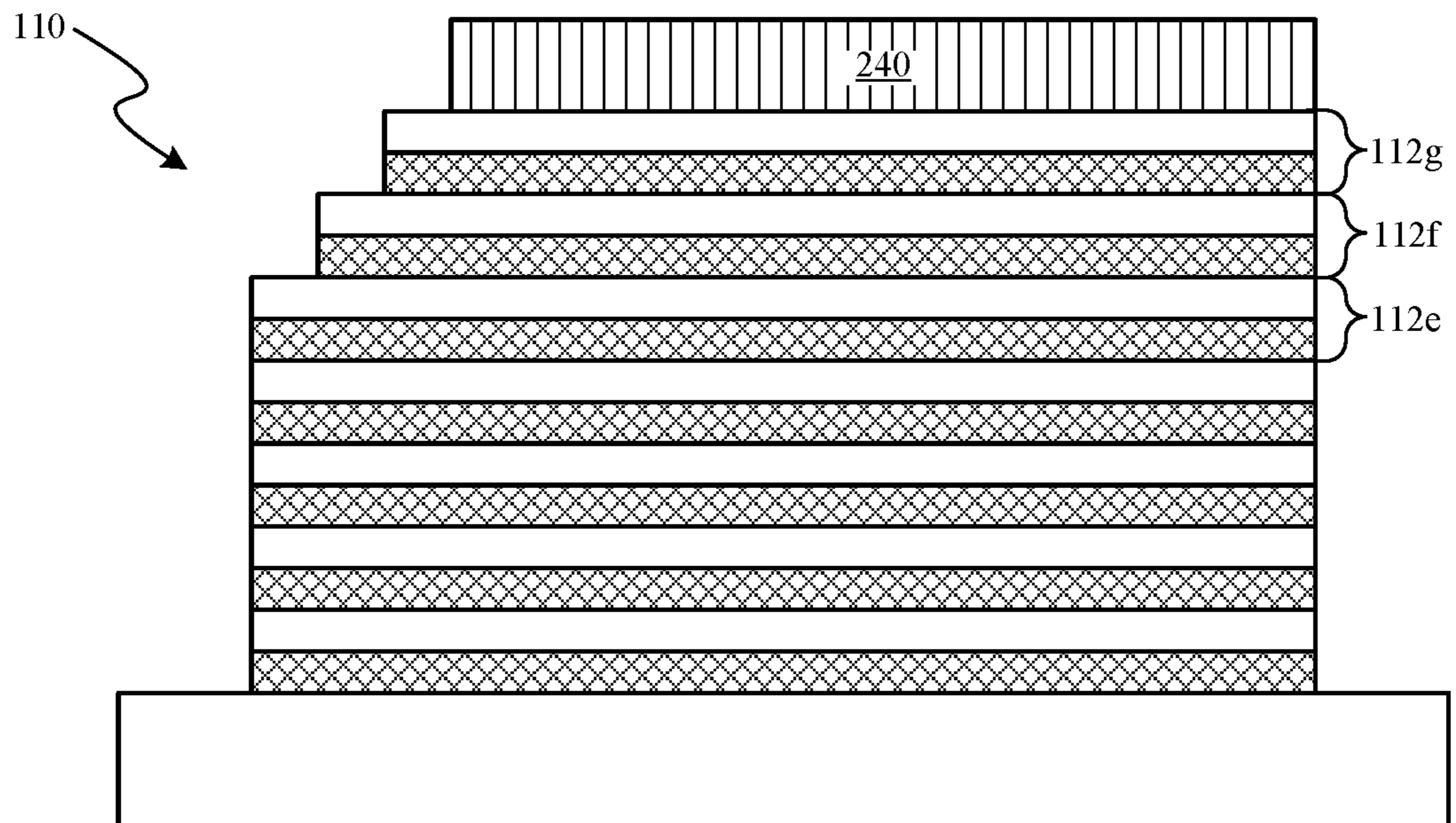


FIG. 2D

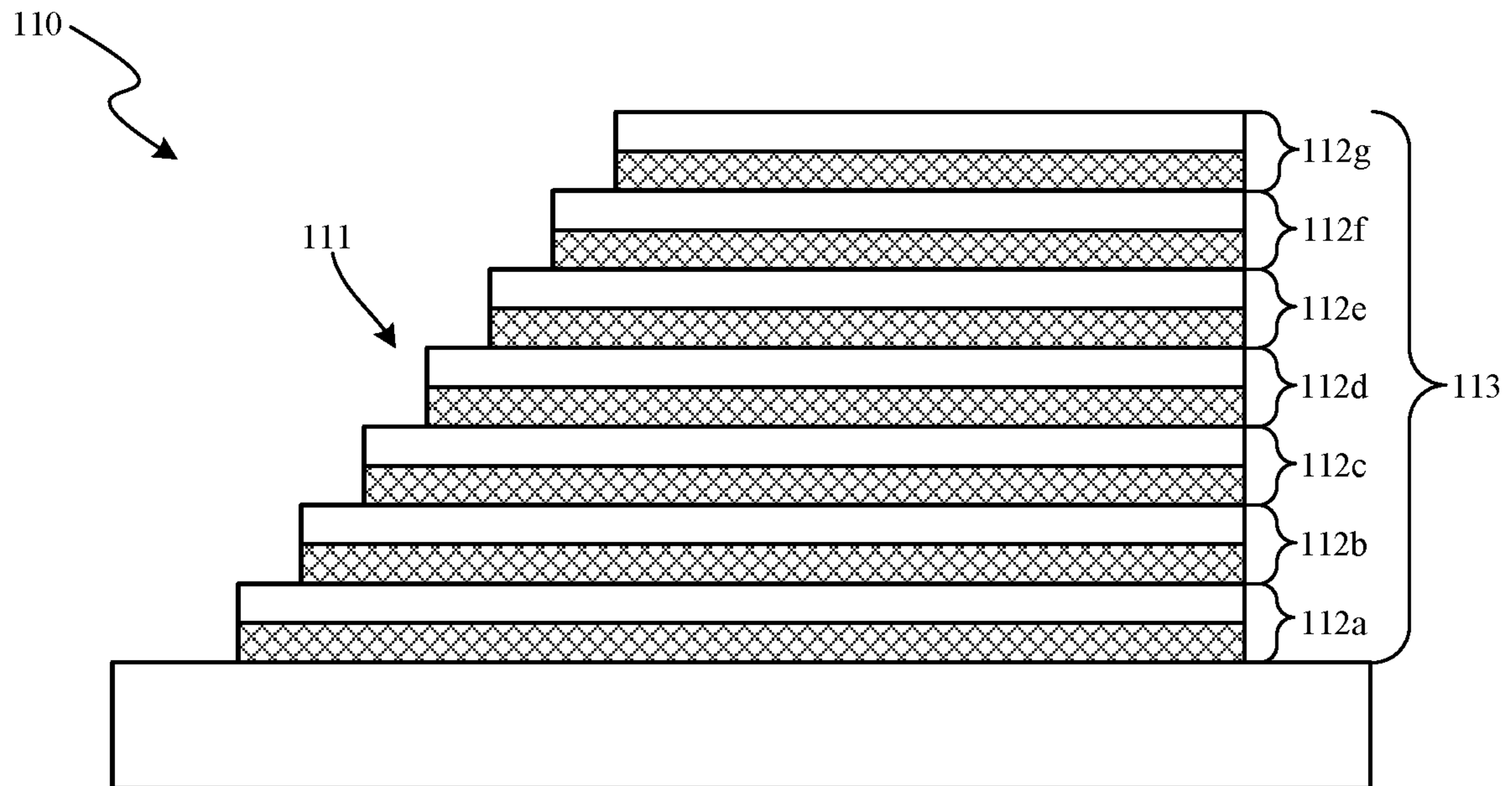


FIG. 2E

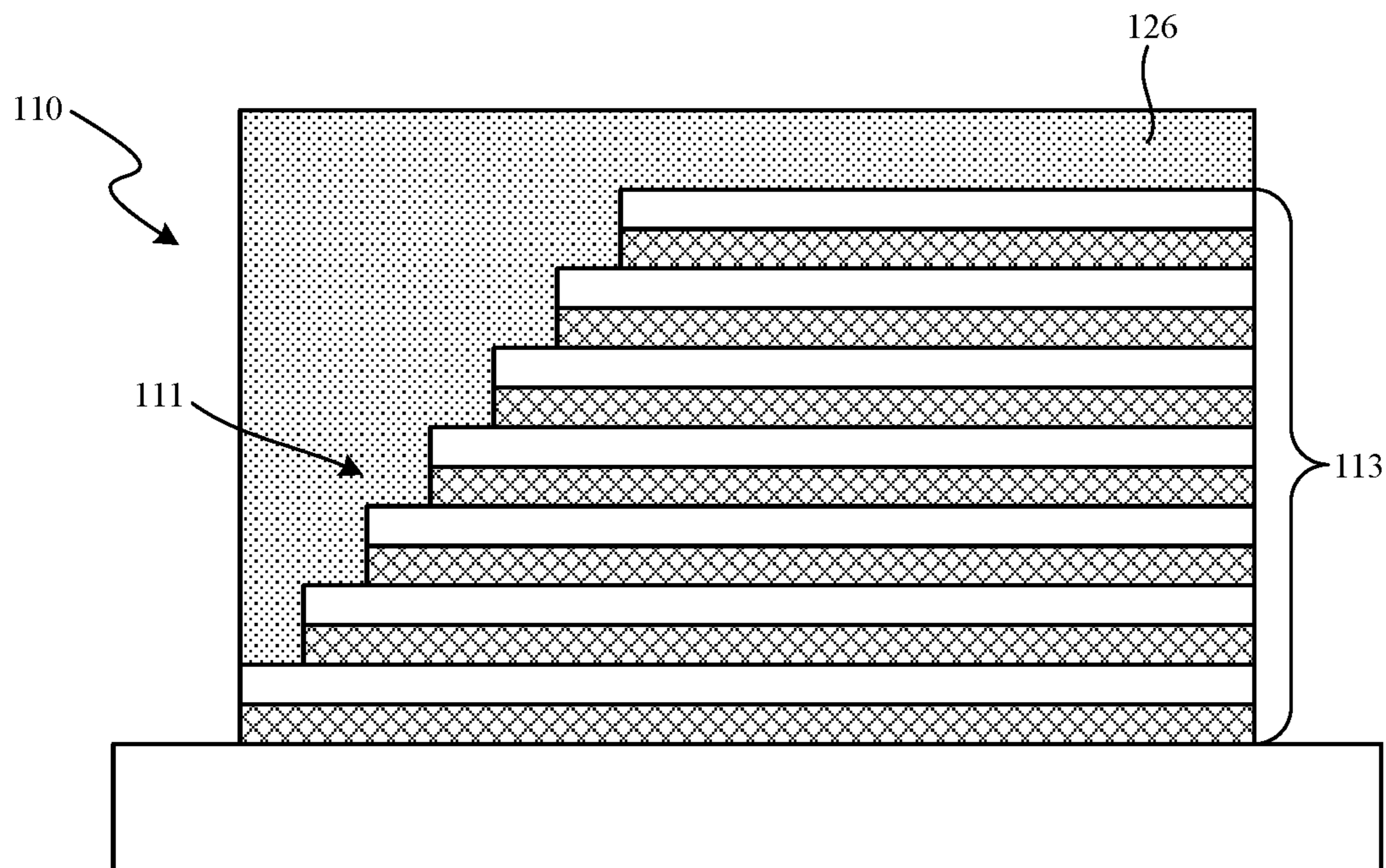


FIG. 2F

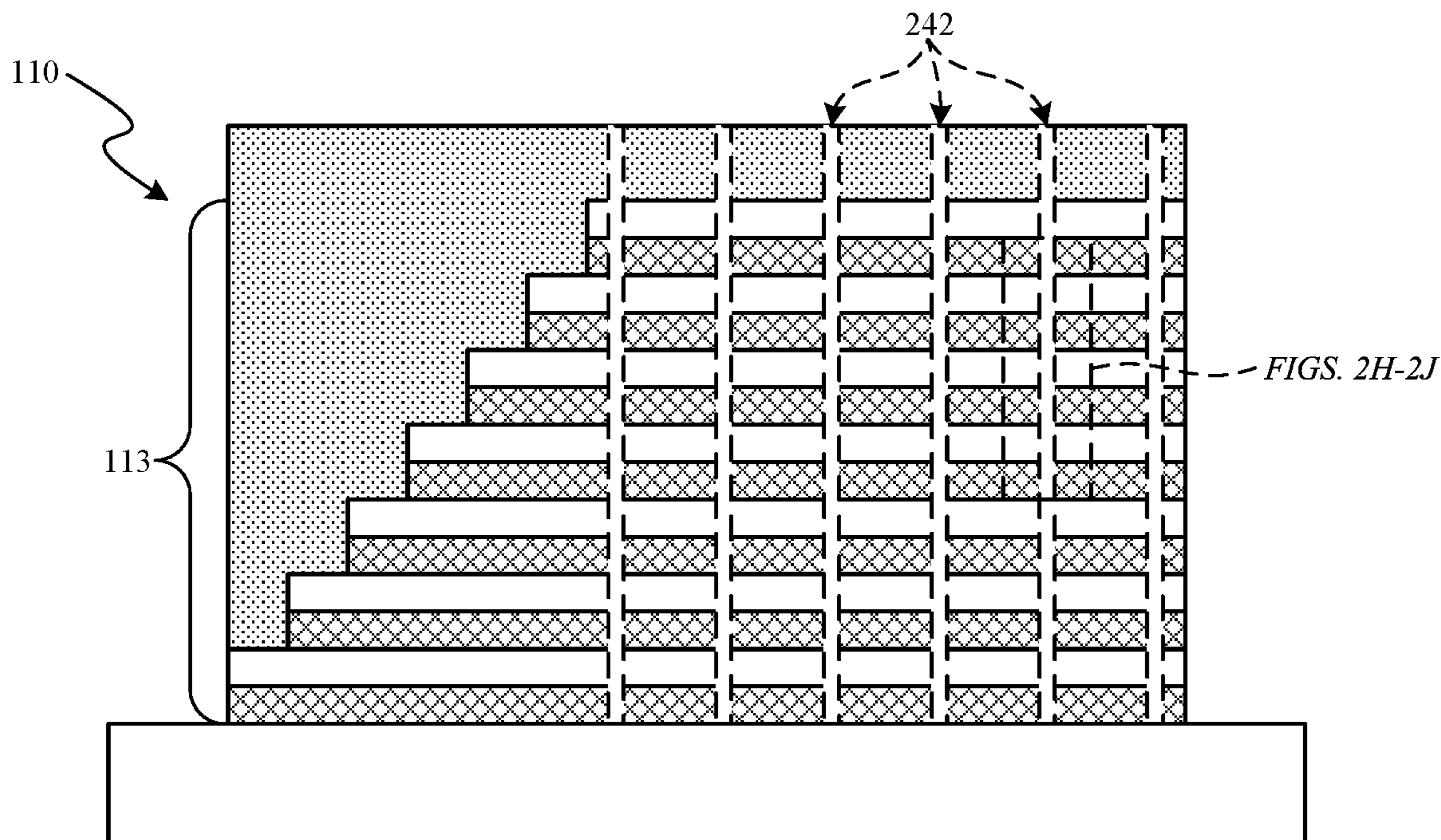


FIG. 2G

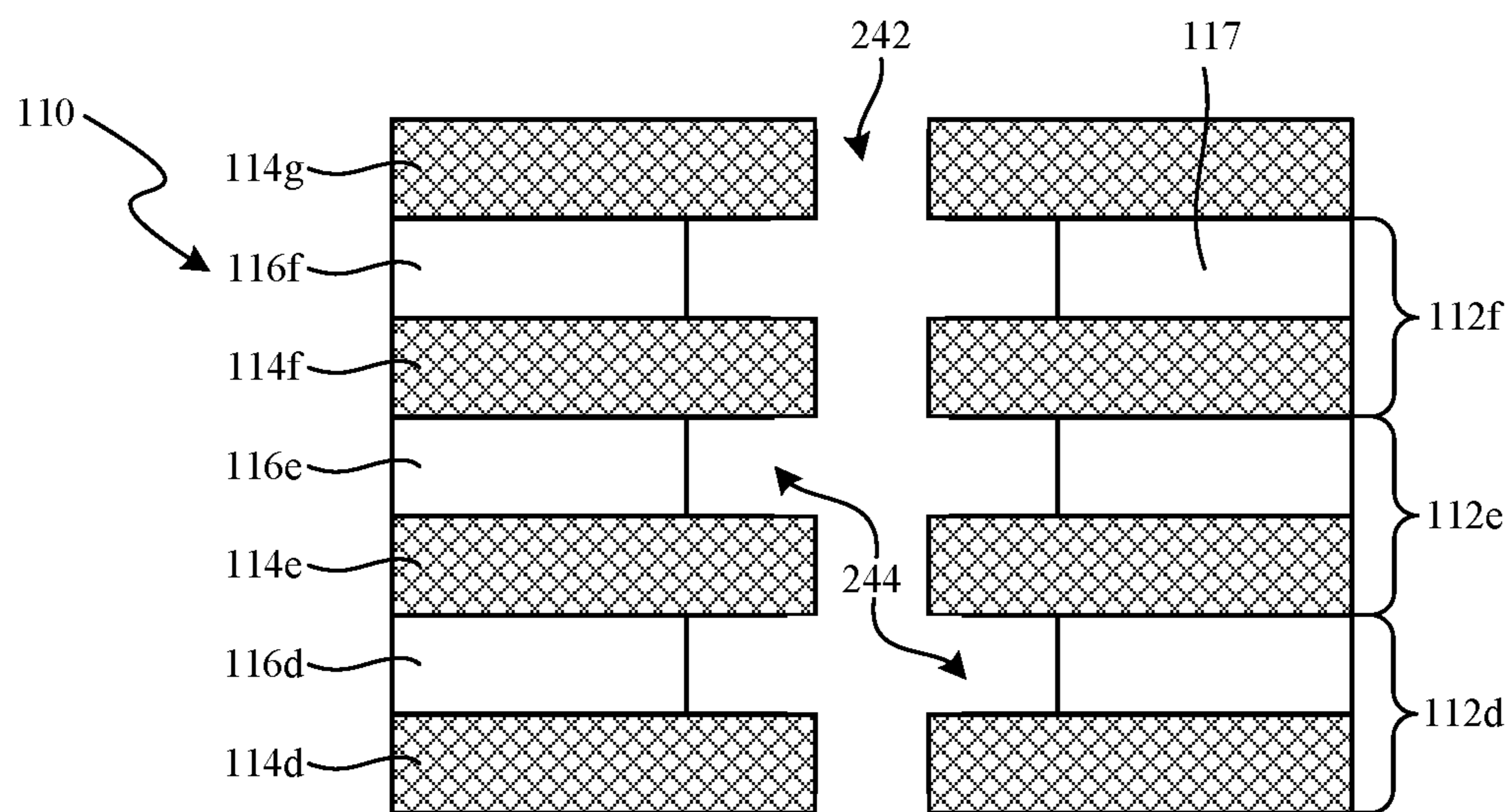


FIG. 2H

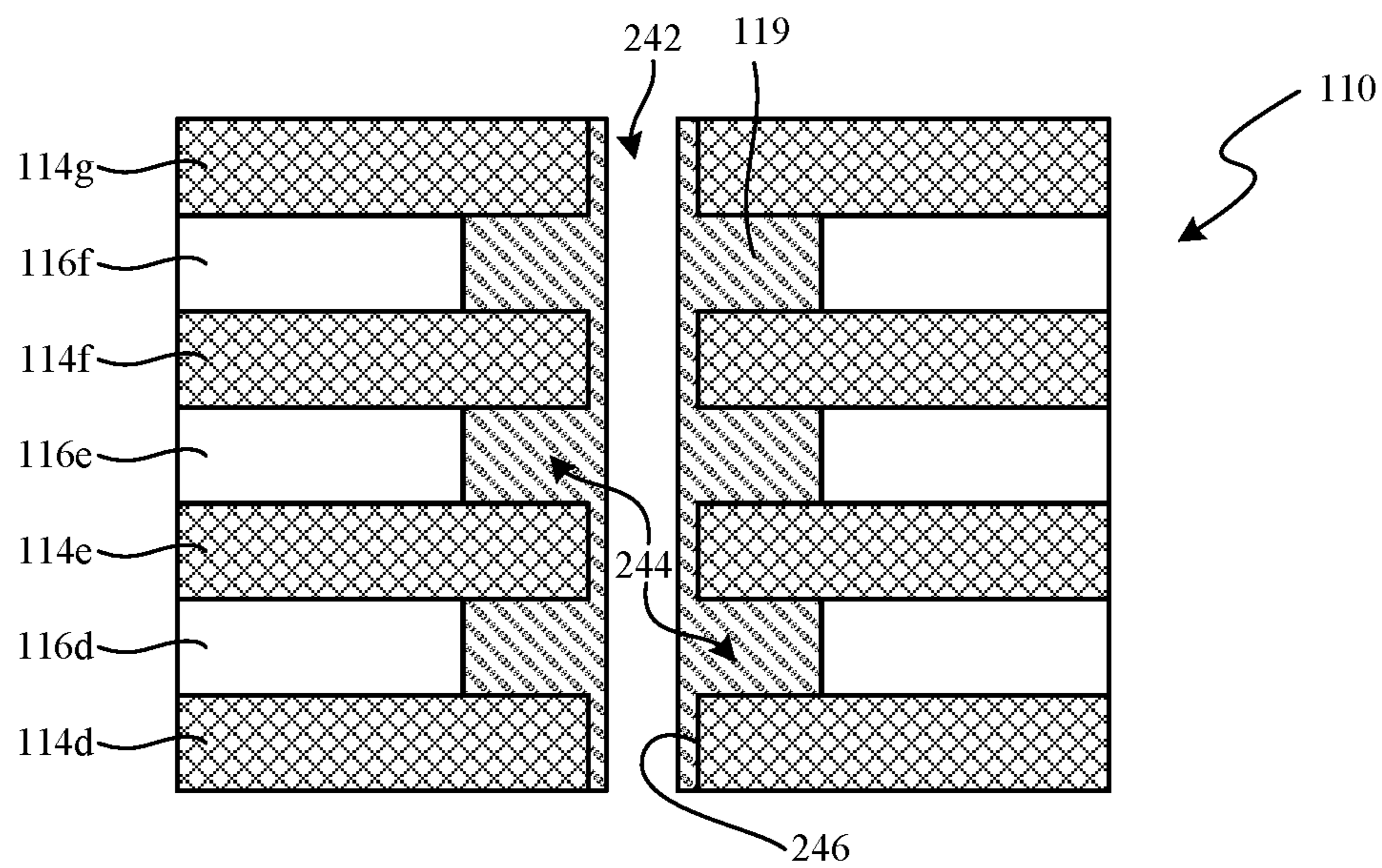


FIG. 2I

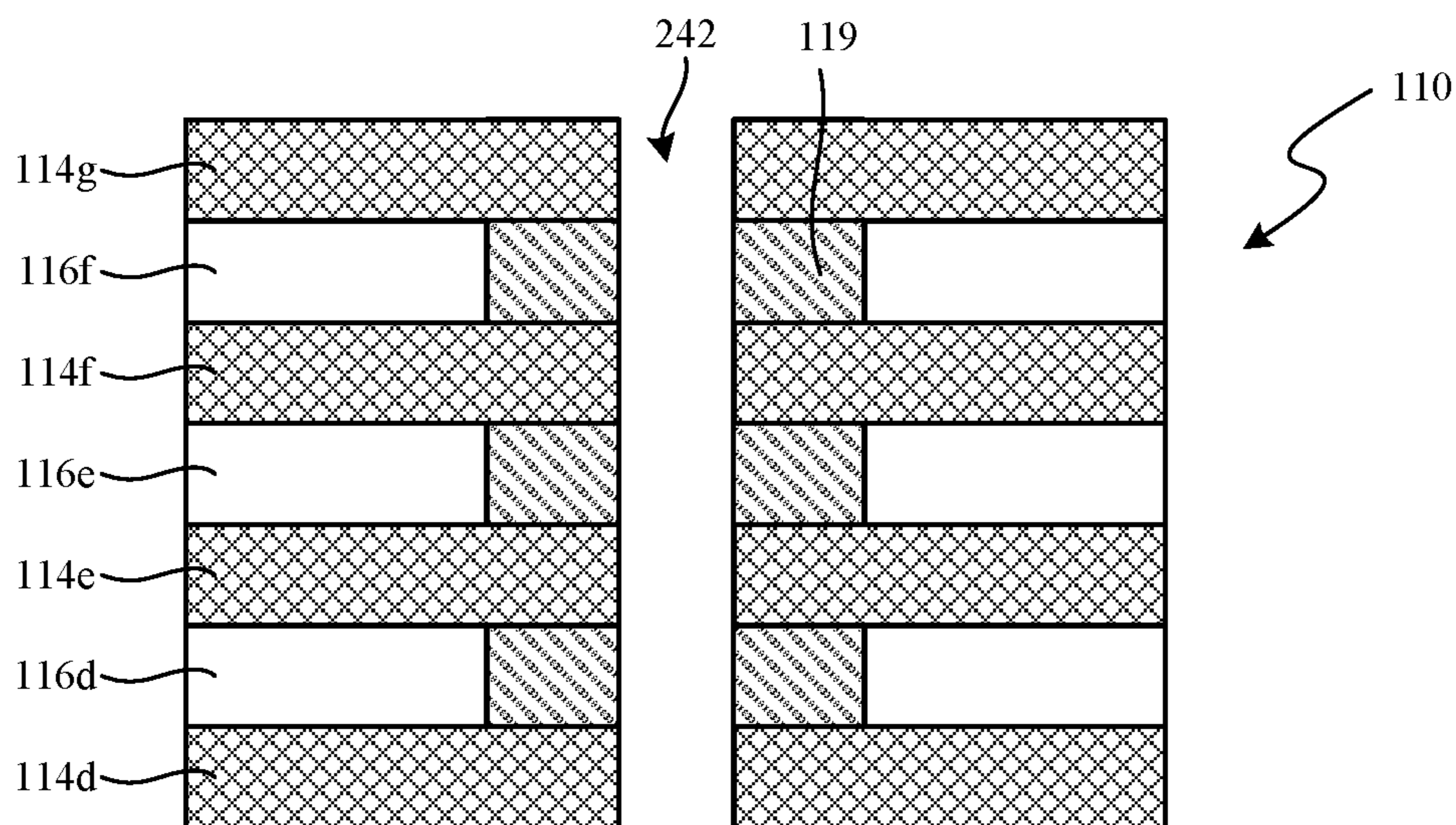


FIG. 2J

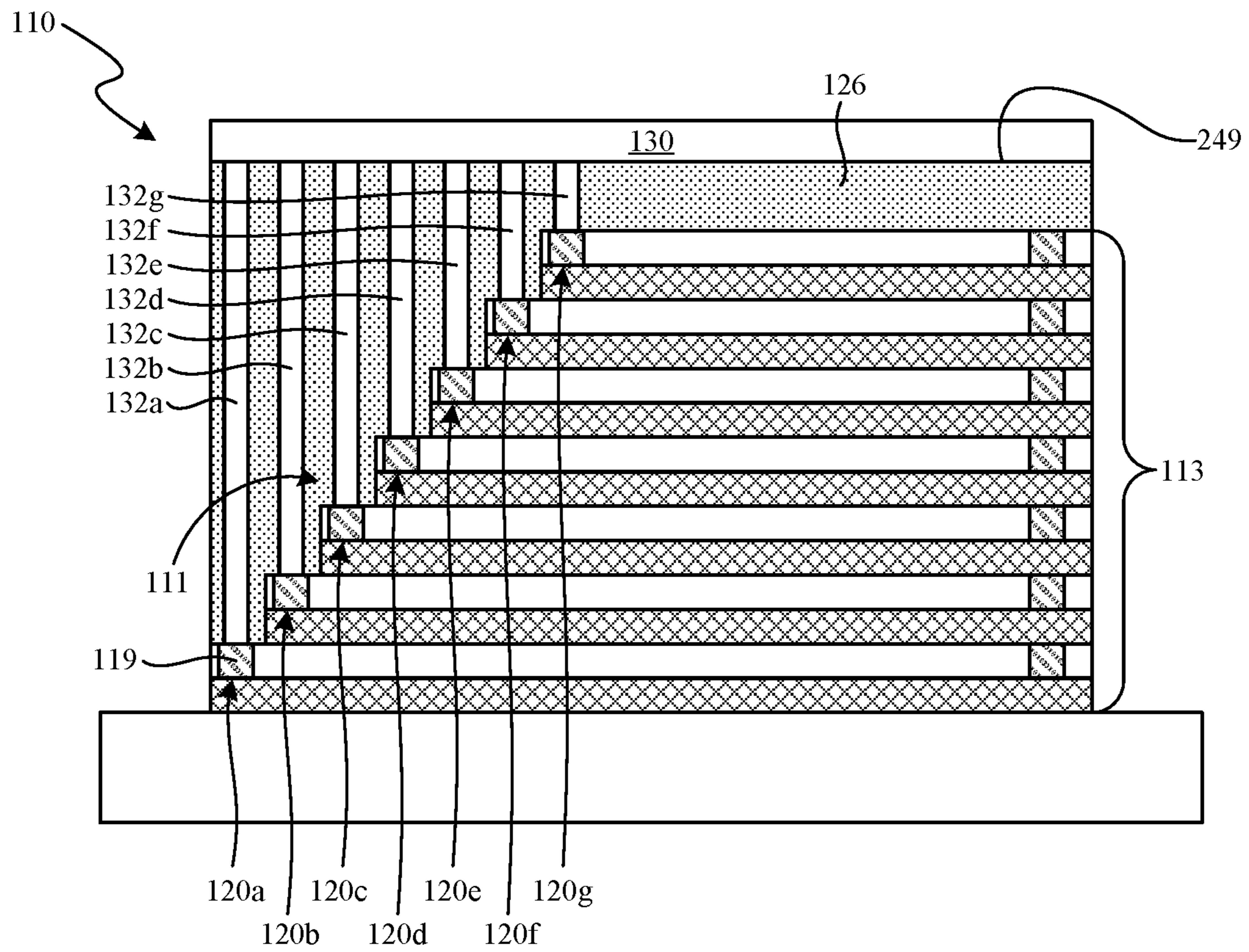


FIG. 2K

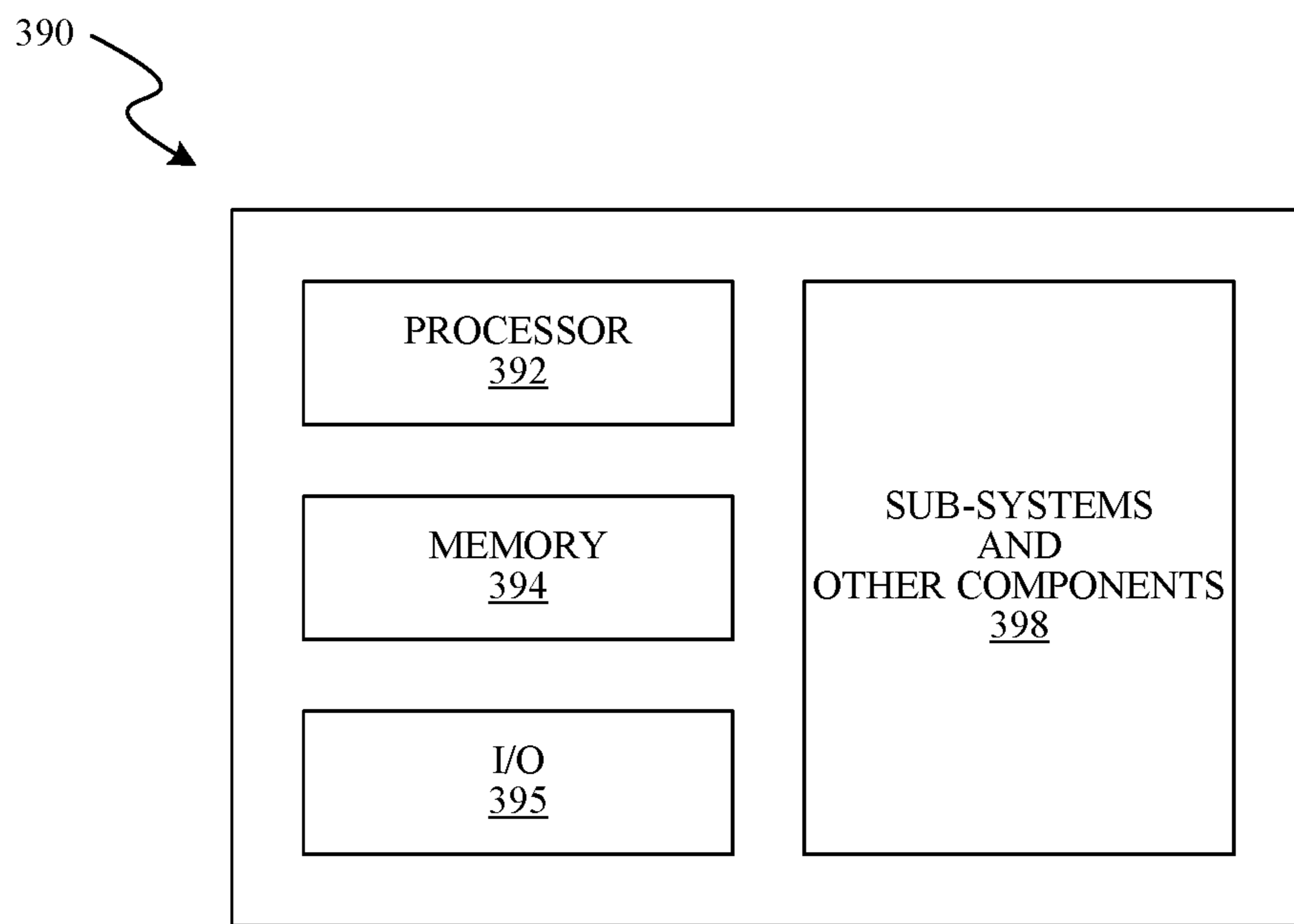


FIG. 3

1

**SEMICONDUCTOR DEVICES HAVING
3-DIMENSIONAL INDUCTIVE STRUCTURES****CROSS-REFERENCE TO RELATED
APPLICATION**

This application is a continuation of U.S. patent application Ser. No. 16/183,057, filed Nov. 7, 2018, and titled “SEMICONDUCTOR DEVICES HAVING 3-DIMENSIONAL INDUCTIVE STRUCTURES,” which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

The present technology generally relates to semiconductor devices having 3-dimensional (3D) inductive structures, and more particularly relates to memory devices having inductive structures comprising vertically-stacked conductive loops.

BACKGROUND

Memory devices are widely used to store information related to various electronic devices such as computers, wireless communication devices, cameras, digital displays, and the like. Information is stored by programming different states of a memory cell. Various types of memory devices exist, such as non-volatile memory devices (e.g., NAND Flash memory devices) and volatile memory devices (e.g., dynamic RAM (DRAM), synchronous dynamic RAM (SDRAM), etc.).

Improving memory devices, generally, may include increasing memory cell density, increasing read/write speeds or otherwise reducing operational latency, increasing reliability, increasing data retention, reducing power consumption, or reducing manufacturing costs, among other metrics. One such other metric is reducing the size or footprint of the memory devices and/or components of the memory devices. Manufacturers achieve size reduction through scaling, various architectural decisions, and/or logic optimizations. One difficulty with reducing the size of a memory device and/or increasing the speed or bandwidth of a memory devices is that such improvements often result in decreased signal integrity—for example, as a result of increased parasitic capacitance within the memory device as conductive members carrying different voltages are positioned nearer to one another or are required to carry higher or more frequent voltages. Such parasitic capacitance can diminish the speed and performance of the memory device.

BRIEF DESCRIPTION OF THE DRAWINGS

Many aspects of the present technology can be better understood with reference to the following drawings. The components in the drawings are not necessarily to scale. Instead, emphasis is placed on illustrating clearly the principles of the present technology.

FIG. 1A is a side cross-sectional view of a portion of a semiconductor device including an inductive structure in accordance with an embodiment of the present technology.

FIG. 1B is a top cross-sectional view of the inductive structure of the semiconductor device shown in FIG. 1A in accordance with an embodiment of the present technology.

FIG. 1C is a schematic view of a metallization structure of the semiconductor device shown in FIG. 1A in accordance with an embodiment of the present technology.

2

FIGS. 2A-2K are side cross-sectional views illustrating various stages in a method of manufacturing the inductive structure of the semiconductor device shown in FIG. 1A in accordance with embodiments of the present technology.

FIG. 3 is a schematic view of a system that includes a semiconductor device in accordance with embodiments of the present technology.

DETAILED DESCRIPTION

Specific details of several embodiments of semiconductor devices having inductive structures, and associated systems and methods, are described below. A person skilled in the relevant art will recognize that suitable stages of the methods described herein can be performed at the wafer level or at the die level. Therefore, depending upon the context in which it is used, the term “substrate” can refer to a wafer-level substrate or to a singulated, die-level substrate. Furthermore, unless the context indicates otherwise, structures disclosed herein can be formed using conventional semiconductor-manufacturing techniques. Materials can be deposited, for example, using chemical vapor deposition, physical vapor deposition, atomic layer deposition, spin coating, and/or other suitable techniques. Similarly, materials can be removed, for example, using plasma etching, wet etching, chemical-mechanical planarization, or other suitable techniques. A person skilled in the relevant art will also understand that the technology may have additional embodiments, and that the technology may be practiced without several of the details of the embodiments described below with reference to FIGS. 1A-3.

A continuing goal of the semiconductor industry has been to increase the memory density (e.g., the number of memory cells per memory die) of memory devices, such as non-volatile memory devices (e.g., NAND Flash memory devices). One way of increasing memory density in non-volatile memory devices is to utilize vertical memory array architectures (“three-dimensional (3D) NAND memory arrays”). A vertical memory array can include, for example, semiconductor pillars extending through openings in tiers of conductive layers or structures (e.g., word line plates, control gate plates, etc.) and electrically insulative materials at each junction of the semiconductor pillars and the conductive structures. Such a configuration permits a greater per-area number of transistors to be located in a memory device by building the array upward (e.g., vertically) on a substrate, as compared to structures with conventional planar (e.g., two-dimensional) arrangements of transistors. Such vertical memory arrays can further include electrical connections between the conductive structures and access lines (e.g., word lines) so that memory cells in the vertical memory array can be uniquely selected for writing, reading, or erasing operations. One method of forming such an electrical connection includes forming a “stair step” structure at edges of the tiers of conductive structures. The stair step structure includes individual “steps” defining contact regions of the conductive structures upon which conductive members (e.g., conductive contacts) can be positioned to provide electrical access to the conductive structures.

Embodiments of the present technology include inductive structures that can have similar architectures to and can utilize similar manufacturing processes as vertical memory arrays. In several of the embodiments described below, for example, an inductive structure includes a plurality of tiers arranged in a stack on a substrate, wherein individual ones of the tiers include a first layer and a second layer over the first layer. The first layers can comprise an electrically

insulative material such as silicon oxide, and the second layers can each include a coil of electrically conductive material (e.g., tungsten) formed therein. The coils of electrically conductive material can be electrically coupled together to form an inductor, and the inductor can be electrically coupled to a vertical memory array and/or another electrical circuit component.

Numerous specific details are disclosed herein to provide a thorough and enabling description of embodiments of the present technology. A person skilled in the art, however, will understand that the technology may have additional embodiments and that the technology may be practiced without several of the details of the embodiments described below with reference to FIGS. 1A-3. For example, some details of semiconductor devices well known in the art have been omitted so as not to obscure the present technology. In general, it should be understood that various other devices and systems in addition to those specific embodiments disclosed herein may be within the scope of the present technology.

As used herein, the terms “vertical,” “lateral,” “upper,” “lower,” “above,” and “below” can refer to relative directions or positions of features in the semiconductor devices in view of the orientation shown in the Figures. For example, “upper” or “uppermost” can refer to a feature positioned closer to the top of a page than another feature. These terms, however, should be construed broadly to include semiconductor devices having other orientations, such as inverted or inclined orientations where top/bottom, over/under, above/below, up/down, and left/right can be interchanged depending on the orientation.

FIG. 1A is a side cross-sectional view of a portion of a semiconductor device **1**, such as a non-volatile (e.g., NAND Flash) memory device in accordance with an embodiment of the present technology. In the illustrated embodiment, the semiconductor device **1** includes a substrate **102** and an inductive structure **110** carried by (e.g., formed on) the substrate **102**. The substrate **102** can include a redistribution layer, an interposer, a printed circuit board, a dielectric spacer, a semiconductor die, or another suitable substrate. The substrate **102** can further carry other passive and/or active electrical circuit components (not pictured). In some embodiments, for example, the semiconductor device **1** can further include a plurality of 3D-NAND memory arrays formed on the substrate **102**. In some embodiments, one or more of the 3D-NAND memory arrays and/or other electrical circuit components can be electrically coupled to the inductive structure **110**.

The inductive structure **110** includes a plurality of tiers **112** (individually labeled as tiers **112a-112g**) arranged in a stack **113** on the substrate **102**. In the illustrated embodiment, the inductive structure **110** includes seven of the tiers **112** for ease of illustration. In practice, however, the inductive structure **110** can include many more tiers such as, for example, more than ten tiers, more than twenty tiers, more than fifty tiers, more than one hundred tiers, etc. In other embodiments, the inductive structure **110** can have fewer than seven tiers. Each of the tiers **112** can have a different lateral width (e.g., in a direction generally parallel to the substrate **102**). More particularly, the lowermost tier **112a** can have the greatest lateral width, and each successive one of the tiers **112b-112g** stacked on the lowermost tier **112a** can have a smaller lateral width than the ones of the tiers **112** stacked below. Accordingly, the stack **113** of tiers **112** can define a stepped portion **111** (e.g., a staircase portion) at which a portion (e.g., a peripheral region) of each one of the

tiers **112** is exposed. In other embodiments, at least a portion of the tiers **112** can have the same lateral width.

In the illustrated embodiment, each of the tiers **112** includes a first layer **114** (individually labeled as first layers **114a-114g**) and a second layer **116** (individually labeled as second layers **116a-116g**) formed over the first layer **114**. Thus, the inductive structure **110** includes a plurality of alternating (e.g., interleaved) first layers **114** and second layers **116**. In some embodiments, each of the layers **114**, **116** is generally planar and has substantially the same thickness. In other embodiments, the layers **114**, **116** can have different and/or varying thicknesses (e.g., some or all of the first layers **114** can be thicker than the second layers **116**, some or all of the second layers **116** can be thicker than the first layers **114**, etc.).

In general, the first layers **114** are formed from (e.g., comprise, include, etc.) at least one electrically insulative material (e.g., a dielectric material) and the second layers **116** are formed from at least one electrically insulative material and at least one electrically conductive material. In some embodiments, for example, the first layers **114** comprise an oxide material **115**, and the second layers **116** comprise a nitride material **117** and a conductive material **119**. In some embodiments, the conductive material **119** can be a metal, metal alloy, a conductive-metal containing material, etc. In a particular embodiment, (i) the oxide material **115** comprises silicon dioxide, (ii) the nitride material **117** comprises silicon nitride, and (iii) the conductive material **119** comprises tungsten.

The conductive material **119** in each of the second layers **116** can form a loop **120** (e.g., a ring, coil, etc.; individually labeled as loops **120a-120g**) having a portion that is exposed (e.g., electrically accessible) at the stepped portion **111** of the stack **113**. More specifically, FIG. 1B is a top cross-sectional view of the inductive structure **110** taken through the second layer **116d** of the (fourth) tier **112d** shown in FIG. 1A, in accordance with an embodiment of the present technology. In the illustrated embodiment, the conductive material **119** of the second layer **116d** forms the loop **120d** having at least a first end portion **121** and a second end portion **123** that are exposed at the stepped portion **111** of the stack **113**. That is, the end portions **121**, **123** can be positioned on the peripheral region of the tier **112d** such that they are laterally outboard of (e.g., not beneath) the (fifth) tier **112e** that is positioned directly above the tier **112d**. In the illustrated embodiment, the loop **120d** has a generally planar, rectilinear shape, and includes only a single winding. In other embodiments, the loop **120d** can have other suitable shapes and configurations (e.g., circular, polygonal, irregular, etc.), can be formed over more or less of the area of the second layer **116d**, and can include more or fewer windings (e.g., as shown in FIGS. 3A and 3B). In some embodiments, the conductive material **119** forming the loop **120d** can have a width of between about 200-1200 nm (e.g., about 470 nm, about 940 nm, etc.).

Referring to FIGS. 1A and 1B together, the loops **120a-120c** and **120e-120g** can be generally similar to the loop **120d** shown in detail in FIG. 1B. In some embodiments, the lowermost loop **120a** can have a greatest dimension (e.g., area, radius, etc.), and the dimension of each successive one of the loops **120b-120g** stacked above the lowermost loop **120a** can be smaller than the dimension of the loop(s) **120** stacked below. In other embodiments, the loops **120** can each be formed to have generally the same dimensions, or can be formed such that one or more upper ones of the loops **120** have a greater dimension than a corresponding dimension of one or more lower ones of the loops **120**. Moreover, in some embodiments, the loops **120** can be formed in only

some of the second layers **116** (e.g., the number of second layers **116** can be greater than the number of loops **120**), or a single second layer **116** can include more than one loop **120** (e.g., the number of loops **120** can be greater than the number of second layers **116**).

The inductive structure **110** further includes an electrically insulative material **126** formed over (i) the stepped portion **111** of the stack **113** and (ii) an upper surface of the second layer **116g** of the (uppermost) tier **112g**. The insulative material **126** can be a passivation, dielectric, or other suitable insulating material such as, for example, silicon oxide, tetraethyl orthosilicate (TEOS), etc. The inductive structure **110** further includes a metallization structure **130** formed on and/or over at least a portion of the insulative material **126** and/or the stack **113**. A plurality of first conductive members **132** (individually labeled as first conductive members **132a-132g**) and a plurality of second conductive members **134** (individually labeled as second conductive members **134a-134g**; obscured in FIG. 1A) can extend through the insulative material **126** to electrically couple the metallization structure **130** to the loops **120**.

More specifically, the conductive members **132**, **134** can extend between and electrically connect the metallization structure **130** and the portion of the loops **120** exposed at the stepped portion **111** of the stack **113**. For example, referring to FIG. 1B, the first conductive member **132d** can be positioned on and/or electrically coupled to the first end portion **121** of the loop **120d**, and the second conductive member **134d** can be positioned on and/or electrically coupled to the second end portion **123** of the loop **120d**. In other embodiments, the conductive members **132**, **134** can be electrically coupled to other portions of the loops **120** (e.g., other than an end portion). The conductive members **132**, **134** can be conductive pillars, columns, studs, etc., and can be formed from one or more conductive materials such as, for example, copper, tungsten, etc. In some embodiments, the conductive members **132**, **134** are identical (e.g., having the same cross-sectional area and shape). In other embodiments, the conductive members **132**, **134** can have differing cross-sectional areas, shapes, etc. Moreover, while the conductive members **132**, **134** are illustrated as generally linearly aligned in FIGS. 1A and 1B, in other embodiments the conductive members **132**, **134** can have other (e.g., non-aligned arrangements) and/or can extend in directions other than vertically through the insulative material **126**.

The metallization structure **130** can be, for example, a redistribution layer or other structure (e.g., including a plurality of conductive traces, vias, routings, etc.) that is configured to electrically couple one or more of the loops **120** together. FIG. 1C, for example, is a schematic view of a portion of the metallization structure **130** and the conductive members **132**, **134** shown in FIG. 1A in accordance with an embodiment of the present technology. In the illustrated embodiment, the metallization structure **130** defines a plurality of first electrical paths **136** (e.g., routings, traces, etc.) that electrically couple individual ones of the first conductive members **132** to corresponding ones of the second conductive members **134** (e.g., to electrically coupled adjacent pairs of the loops **120** in the stack **113**). For example, the metallization structure **130** can electrically couple the second conductive member **134d** of the (fourth) tier **112d** to the first conductive member **132e** of the (fifth) tier **112e**. Therefore, in the illustrated embodiment, the metallization structure **130** electrically couples the loops **120** together in series to define a continuous electrical path that forms an inductor. In other embodiments, the loops **120** can be electrically coupled together in other suitable arrangements.

The metallization structure **130** can further define second electrical paths **138** for coupling the inductive structure **110** to other electrical circuit components (not pictured) such as one or more bond pads of the semiconductor device **1** and/or one or more 3D-NAND memory arrays formed on the substrate **102**. In this manner, the inductive structure **110** can be coupled to a circuit (e.g., and I/O (in/out) data circuit) of the semiconductor device **1** and/or a circuit that is external to the semiconductor device **1**. The inductance of a circuit depends in part on the geometry of the current path through the circuit. In particular, the number of loops (e.g., windings or turns) in the current path can increase the magnetic flux generated by the current and thus the inductance of the circuit. Therefore, the multiple loops **120** of the inductive structure **110** can increase the total inductance of a circuit coupled to the inductive structure **110**. Moreover, the number of loops **120** of the inductive structure **110** can be equal to, for example, the number of tiers **112** in the stack **113**. Therefore, the inductance of the inductive structure **110** can be selected based at least in part on the number of tiers **112** in the stack **113** and/or the configuration of the loops **120** (e.g., the dimensions of the loops **120**).

Semiconductor manufacturers are continually striving to increase the inductance of semiconductor devices as requirements for speed and data rates continue to increase, and analog (rather than digital) signaling becomes more prevalent. The inductive structure **110** can advantageously provide a large inductance while consuming relatively little space within the semiconductor device **1** due to the vertical stacking of the loops **120**. In some embodiments, the inductive structure **110** can form a portion of a RLC shunt that can effectively increase the signal integrity of, for example, I/O data signals to the semiconductor device **1**. In some embodiments, the inductive structure **110** can form part of an electrostatic discharge (ESD) circuit that can effectively protect other components in the semiconductor device **1** from large voltage discharges that may damage those components. For example, the inductive structure **110** can be configured to trigger an ESD protection circuit. In still further embodiments, the inductive structure **110** can form part of a signaling circuit—for example, an inductive signaling circuit that permits signaling between separate (e.g., stacked) semiconductor devices.

FIGS. 2A-2K are side cross-sectional views illustrating various stages in a method of manufacturing the inductive structure **110** in accordance with embodiments of the present technology. Generally, the inductive structure **110** can be manufactured, for example, as a discrete device or as part of a larger wafer or panel. In wafer-level or panel-level manufacturing, a larger structure is formed before being singulated to form a plurality of individual structures. For ease of explanation and understanding, FIGS. 2A-2K illustrate the fabrication of a single inductive structure **110**. However, one skilled in the art will readily understand that the fabrication of the inductive structure **110** can be scaled to the wafer and/or panel level—that is, to include many more components so as to be capable of being singulated into two or more inductive structures **110**—while including similar features and using similar processes as described herein.

Referring first to FIG. 2A, fabrication of the inductive structure **110** begins with the formation of the stack **113** of the tiers **112** on the substrate **102**. The alternating first layers **114** and second layers **116** can be formed using processes well known in the art such as, for example, film deposition, chemical vapor deposition, physical vapor deposition, atomic layer deposition, spin coating, and/or other suitable

techniques. Upon formation, the second layers **116** comprise only the nitride material **117** and do not yet include the conductive material **119**.

Referring to FIG. 2B, at this stage of the method a mask **240** (e.g., a photomask) is formed on an upper surface of the second layer **116g** of the uppermost (seventh) tier **112g**. The mask **240** can be a resist material or other suitable mask, and can have a width that is less than a width of the tier **112g** after it is initially formed (FIG. 3A) such that a portion of the tier **112g** is exposed from the mask **240**.

FIG. 2C illustrates the inductive structure **110** after the exposed portion of the tier **112g** has been removed using, for example, a suitable etching process (e.g., an anisotropic etching process, a dry etching process, a plasma etching process, wet etching process, and/or other suitable etching process). As shown, portions of both the layers **114g** and **116g** are removed. After removing the portions of the layers **114g** and **116g**, a portion of the (sixth) tier **112f** is exposed. FIG. 2C further illustrates the inductive structure **110** after a portion of the mask **240** has been selectively removed to expose another portion of the tier **112g**. The portion of the mask **240** can be removed using plasma etching, wet etching, chemical-mechanical planarization, or other suitable techniques.

FIG. 2D illustrates the inductive structure **110** after the exposed portions of the tiers **112f** and **112g** have been removed to expose a portion of the (fifth) tier **112e**. FIG. 2D further illustrates the inductive structure **110** after a portion of the mask **240** has been selectively removed to expose another portion of the tier **112g**. As shown in FIG. 2E, the process of (i) removing a portion of the mask **240** and subsequently (ii) removing (e.g., etching) the stack **113** of the tiers **112** can be repeated to form the stepped portion **111** of the stack **113**. Once the stepped portion **111** is fully formed, the mask **240** can be removed as shown in FIG. 2E.

Referring to FIG. 2F, at this stage of the method the insulative material **126** is deposited or otherwise formed over (i) the stepped portion **111** of the stack **113** and (ii) the upper surface of the second layer **116g** of the uppermost tier **112g**. In some embodiments, once deposited, the insulative material **126** can be cured by UV light, chemical hardeners, heat, or other suitable curing methods known in the art. FIG. 2G illustrates the inductive structure **110** after etching a plurality of high-aspect ratio holes **242** (shown schematically) through the stack **113**. The high-aspect ratio holes **242** can be formed using photolithography and/or etching processes known in the art.

FIGS. 2H-2J are enlarged views illustrating subsequent processing steps on a portion of the stack **113** shown in FIG. 2G. Referring to FIG. 2F, at this stage of the method the second layers **116** are selectively removed (e.g., etched back) to form one or more recesses **244** in the second layers **116**. In some embodiments, for example, a nitride-selective etchant (e.g., a wet or dry etch material) can be introduced into the high-aspect ratio holes **242** to selectively remove the nitride material **117** of the second layers **116**.

FIG. 2I illustrates the inductive structure **110** after depositing the conductive material **119** in the high-aspect ratio holes **242** and in the recesses **244**. The conductive material **119** can be deposited via chemical vapor deposition, physical vapor deposition, atomic layer deposition, spin coating, electroplating, electro-less plating, and/or other suitable techniques. As further shown in FIG. 2I, after deposition, the conductive material **119** can at least partially cover or coat a sidewall **246** of the inductive structure **110** that defines the high-aspect ratio hole **242**. To isolate the conductive material **119** to the second layers **116** (and prevent electrical

shorting), the conductive material **119** can be etched or otherwise removed from the high-aspect ratio holes **242** as shown in FIG. 2J.

In the embodiments illustrated in FIGS. 2H-2J, the recesses **244** are formed in each of the second layers **116** and the conductive material **119** is formed in each of the recesses **244**. In general, however, the manufacturing stages illustrated in FIGS. 2H-2J can include selectively masking some or all of the high-aspect ratio holes **242** and/or portions of the high-aspect ratio holes **242** to form the desired shape and placement of the loops **120** within the second layers **116**.

FIG. 2K, for example, shows the inductive structure **110** after forming the loops **120** in the second layers **116**. FIG. 2K further illustrates the inductive structure **110** after forming the first conductive members **132** and the second conductive members **134** (obscured in FIG. 2K). The conductive members **132**, **134** can be formed by (i) etching holes through the insulative material **126** from an upper surface **249** of the insulative material **126** to the portions of the conductive material **119** exposed at the stepped portion **111** of the stack **113**, and (ii) depositing a conductive material into the holes etched in the insulative material **126** (e.g., via chemical vapor deposition, physical vapor deposition, atomic layer deposition, spin coating, electroplating, electro-less plating, and/or other suitable techniques). In some embodiments, the conductive material **119** exposed at the stepped portion **111** of the stack **113** can serve as an etch-stop that inhibits further etching of the inductive structure **110**.

FIG. 2K also illustrates the inductive structure **110** after formation of the metallization structure **130** on the upper surface **249** of the insulative material **126** and over upper end portions of the conductive members **132**, **134**. The metallization structure **130** can be formed by an additive build up process (e.g., depositing one or more layers of insulative and conductive material on the upper surface **249** of the insulative material **126**), by directly electrically connecting the upper end portions of the conductive members **132**, **134** (e.g., via metal traces, wirebonds, etc.), and/or by other suitable methods.

Notably, the method of manufacturing the inductive structure **110** illustrated in FIGS. 2A-2K can include some steps generally similar to the fabrication of a 3D-NAND memory array. As described in detail above, for example, the method can include (i) forming a structure of alternating oxide and nitride layers having a staircase, (ii) etching high aspect-ratio holes through the structure, (iii) and selectively removing some or all of the nitride layers. However, instead of forming a plurality of memory cells electrically coupled to the plurality of word lines, each tier of the structure can be formed to include one of the loops **120** of conductive material **119** (FIGS. 2H-2J). Accordingly, in some embodiments, the semiconductor device **1** can be a 3D-NAND memory device (e.g., having 3D-NAND memory arrays on the substrate **102**) and the inductive structure **110** can be formed as an extension of the process used to form the 3D-NAND memory arrays.

Any one of the semiconductor devices and/or packages having the features described above with reference to FIGS. 1A-2K can be incorporated into any of a myriad of larger and/or more complex systems, a representative example of which is system **390** shown schematically in FIG. 3. The system **390** can include a processor **392**, a memory **394** (e.g., SRAM, DRAM, flash, and/or other memory devices), input/output devices **395**, and/or other subsystems or components **398**. The semiconductor dies and/or packages described above with reference to FIGS. 1A-2K can be included in any

9

of the elements shown in FIG. 3. The resulting system 390 can be configured to perform any of a wide variety of suitable computing, processing, storage, sensing, imaging, and/or other functions. Accordingly, representative examples of the system 390 include, without limitation, computers and/or other data processors, such as desktop computers, laptop computers, Internet appliances, hand-held devices (e.g., palm-top computers, wearable computers, cellular or mobile phones, personal digital assistants, music players, etc.), tablets, multi-processor systems, processor-based or programmable consumer electronics, network computers, and minicomputers. Additional representative examples of the system 390 include lights, cameras, vehicles, etc. With regard to these and other example, the system 390 can be housed in a single unit or distributed over multiple interconnected units, for example, through a communication network. The components of the system 390 can accordingly include local and/or remote memory storage devices and any of a wide variety of suitable computer-readable media.

From the foregoing, it will be appreciated that specific embodiments of the technology have been described herein for purposes of illustration, but that various modifications may be made without deviating from the disclosure. Accordingly, the invention is not limited except as by the appended claims. Furthermore, certain aspects of the new technology described in the context of particular embodiments may also be combined or eliminated in other embodiments. Moreover, although advantages associated with certain embodiments of the new technology have been described in the context of those embodiments, other embodiments may also exhibit such advantages and not all embodiments need necessarily exhibit such advantages to fall within the scope of the technology. Accordingly, the disclosure and associated technology can encompass other embodiments not expressly shown or described herein.

We claim:

1. An inductive structure, comprising:
 - a plurality of layers of electrically insulative material arranged in a stack, wherein the layers are at least partially offset from one another to define a stepped portion of the stack, and wherein each of the layers includes a peripheral region that is exposed from the stack at the stepped portion;
 - a plurality of loops of electrically conductive material formed in corresponding ones of the layers; and
 - a metallization structure over the stack and electrically coupling the loops together.
2. The inductive structure of claim 1 wherein the loops are electrically accessible at the stepped portion.
3. The inductive structure of claim 2, further comprising a plurality of conductive columns extending between the stepped portion of the stack and the metallization structure, wherein the conductive columns electrically couple the metallization structure to the loops.
4. The inductive structure of claim 1, further comprising an oxide material over the stepped portion of the stack.
5. The inductive structure of claim 4 wherein the oxide material is further over an uppermost layer of the plurality of layers.
6. The inductive structure of claim 1 wherein the loops are electrically coupled together in series.
7. The inductive structure of claim 1 wherein individual ones of the loops include a first end portion and a second end portion, wherein the first and second end portions are positioned at the stepped portion of the stack.

10

8. The inductive structure of claim 7, further comprising a plurality of conductive columns, wherein individual ones of the conductive columns are connected to the first end portion of a corresponding one of the loops or the second end portion of a corresponding one of the loops.

9. The inductive structure of claim 1 wherein the electrically insulative material of each of the layers comprises a first insulative material over a second insulative material.

10. The inductive structure of claim 9 wherein the first insulative material comprises an oxide material, wherein the second insulative material comprises a nitride material, and wherein the electrically conductive material of the loops comprises tungsten.

11. An inductive structure, comprising:

a substrate;

a stack of tiers carried by the substrate, wherein individual ones of the tiers include a first layer including an insulative material and a second layer including a loop of conductive material, wherein the stack includes a staircase portion at which a peripheral region of each of the tiers is exposed from the stack, wherein a portion of each of the loops of conductive material is exposed at the peripheral region, wherein the insulative material is an oxide material, wherein the conductive material is tungsten, and wherein the second layers further include a nitride material at least partially around the tungsten; and

a metallization structure carried by the substrate, wherein the loops of conductive material are electrically coupled to the metallization structure.

12. The inductive structure of claim 11 wherein the metallization structure electrically couples the loops together such that they form an inductor.

13. The inductive structure of claim 12 wherein the metallization structure electrically couples the inductor to a 3D-NAND memory array.

14. The inductive structure of claim 13 wherein the 3D-NAND memory array is carried by the substrate.

15. The inductive structure of claim 11 wherein the metallization structure electrically couples the loops together in series.

16. The inductive structure of claim 11, wherein the loops have different radii.

17. The inductive structure of claim 11, further comprising:

an oxide material over the staircase portion of the stack; and

a plurality of conductive members extending through the oxide material between the metallization structure and corresponding ones of the loops of conductive material.

18. The inductive structure of claim 11 wherein the first and second layers are generally planar.

19. The inductive structure of claim 11 wherein individual ones of the first layers are covered by an adjacent one of the second layers at the staircase portion of the stack.

20. A memory device, comprising:

a substrate;

a 3D-NAND memory array carried by the substrate; and an inductive structure carried by the substrate, wherein the inductive structure includes—

a plurality of layers of electrically insulative material arranged in a stack, wherein the layers are at least partially offset from one another to define a stepped portion of the stack, and wherein each of the layers includes a peripheral region that is exposed from the stack at the stepped portion;

11

a plurality of loops of electrically conductive material
formed in corresponding ones of the layers; and
a metallization structure over the stack and electrically
coupling the loops together, wherein the metalliza-
tion structure electrically couples the inductor to the 5
3D-NAND memory array.

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12